AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-10177

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

OPEN FIELD SCORING RECORD NO. 917

SITE LOCATION:
U.S. ARMY YUMA PROVING GROUND

DEMONSTRATOR:
GAP GEOPHYSICS AUSTRALIA PTY LTD (GAP)
P.O. BOX 3789
SOUTH BRISBANE, BC QLD 4101

TECHNOLOGY TYPE/PLATFORM:
DUAL MODE SAM/TOWED

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

JANUARY 2010

Prepared for:
U.S. ARMY ENVIRONMENTAL COMMAND
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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TEDT-AT-SLE

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1. The attached document entitled "Scoring Record No. 917" dated January 2010 is provided for review for public disclosure in accordance with AR 530-1 as supplemented. The document is proposed for public release via the internet.

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14. ABSTRACT

This scoring record documents the efforts of Gap to detect and discriminate inert unexploded ordnance (UXO) utilizing the YPG Standardized UXO Technology Demonstration Site open field. This Scoring Record was coordinated by J. Stephen McClung and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.

15. SUBJECT TERMS
Gap, YPG, Standardized UXO Technology Demonstration Site; open field; Dual Mode SAM/Towed

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of munitions and explosives of concern (MEC) – i.e., unexploded ordnance (UXO) and discarded military munitions (DMM) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland, and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the Government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multiagency program spearheaded by the U.S. Army Environmental Command (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP), and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine the demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance (i.e., that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. Based on configuration of the ground truth at the standardized sites and the defined scoring methodology, there exists the possibility of having anomalies within overlapping halos and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular ground truth item.

(2) For overlapping R_{halo} situations, ordnance has precedence over clutter. The anomaly with the strongest response or highest ranking that is closest to the center of a particular ground truth item gets assigned to that item. Remaining anomalies are retained until all matching is complete.

(3) Anomalies located within any R_{halo} that do not get associated with a particular ground truth item are thrown out and are not considered in the analysis.

f. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time, and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert ordnance items having properties that differ from those in the set of standardized targets.

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm HEAT Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb

JPG = Jefferson Proving Ground.
HEAT = high-explosive antitank.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC: Mr. Stephen Griffin
+61 7 5535 1889

Address: Gap Geophysics Australia Pty Ltd (Gap)
P.O. Box 3789
South Brisbane, BC Qld 4101

2.1.2 System Description (provided by demonstrator)

Information requested for this section was not provided by the demonstrator.

Figure 1. Gap, Dual Mode, SAM/towed.

2.1.3 Data Processing Description (provided by demonstrator)

Information requested for this section was not provided by the demonstrator.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect ground truth information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

Information requested for this section was not provided by the demonstrator.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as Microsoft Word documents at www.uxotestsites.org.

2.2 YPG SITE INFORMATION

2.2.1 Location

YPG is located adjacent to the Colorado River in the Sonoran Desert. The UXO Standardized Test Site is located south of Pole Line Road and east of the Countermine Testing and Training Range. The open field range, calibration grid, blind grid, mogul area, and desert extreme area comprise the 350- by 500-meter general test site area. The open field site is the largest of the test sites and measures approximately 200 by 350 meters. To the east of the open field range are the calibration and blind test grids that measure 30 by 40 meters and 40 by 40 meters, respectively. South of the open field is the 135- by 80-meter mogul area consisting of a sequence of man-made depressions. The desert extreme area is located southeast of the open field site and has dimensions of 50 by 100 meters. The desert extreme area, covered with desert-type vegetation, is used to test the performance of different sensor platforms in a more severe desert conditions/environment.

2.2.2 Soil Type

Soil samples were collected at the YPG UXO Standardized Test Site by ERDC to characterize the shallow subsurface (< 3 m). Both surface grab samples and continuous soil borings were acquired. The soils were subjected to several laboratory analyses, including sieve/hydrometer, water content, magnetic susceptibility, dielectric permittivity, X-ray diffraction, and visual description.

Two soil complexes are present within the site: Riverbend-Carrizo and Cristobal-Gunsight. The Riverbend-Carrizo complex is composed of mixed stream alluvium, whereas the Cristobal-Gunsight complex is derived from fan alluvium. The Cristobal-Gunsight complex covers the majority of the site. Most of the soil samples were classified as either a sandy loam or loamy sand, with most samples containing gravel-size particles. All samples had a measured water content less than 7 percent, except for two that contained 11-percent moisture. The majority of soil samples had water content between 1 and 2 percent. Samples containing more than 3 percent were generally deeper than 1 meter.

An X-ray diffraction analysis on four soil samples indicated a basic mineralogy of quartz, calcite, mica, feldspar, magnetite, and some clay. The presence of magnetite imparted a moderate magnetic susceptibility, with volume susceptibilities generally greater than 100 by 105 SI.

For more details concerning the soil properties at the YPG test site, go to www.uxotestsites.org on the Web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at YPG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration grid	Contains the 15 standard ordnance items buried in six positions at various angles and depths to allow demonstrator equipment calibration.
Blind grid	Contains 400 grid cells in a 0.16-hectare (0.39-acre) site. The center of each grid cell contains ordnance, clutter, or nothing.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (18 through 21, 23 through 28, and 30 June and 1 and 2 July 2008)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	No. of Hours
Calibration lanes	5.92
Open field	105.31

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

A YPG weather station located approximately 1 mile west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours, while precipitation data represent a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 08	Average Temperature, ^{o}F	Total Daily Precipitation, in.
18 Jun	85.9	0.00
19 Jun	102.4	0.00
20 Jun	104.2	0.00
21 Jun	102.0	0.00
23 Jun	102.4	0.00
24 Jun	99.4	0.00
25 Jun	98.7	0.00
26 Jun	95.6	0.00
27 Jun	98.9	0.00
28 Jun	100.3	0.00
30 Jun	NA	0.00
1 Jul	NA	0.00
2 Jul	NA	0.00

3.3.2 <u>Field Conditions</u>

Gap experienced a dry field and hot weather throughout the survey.

3.3.3 <u>Soil Moisture</u>

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, calibration, mogul, and desert areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are included in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 <u>Setup/Mobilization</u>

These activities included initial mobilization and daily equipment preparation and breakdown. A five-person crew took 12 hours and 5 minutes to perform the initial setup and mobilization. There were 8 hours and 46 minutes of daily equipment preparation, and end of the day equipment breakdown lasted 2 hours and 39 minutes.

3.4.2 <u>Calibration</u>

Gap spent a total of 5 hours and 55 minutes in the calibration lanes, of which 2 hours and 55 minutes were spent collecting data.

3.4.3 <u>Downtime Occasions</u>

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, demonstration site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to demonstration site issues. Demonstration site issues, while noted in the daily log, are considered non-chargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total site survey area.

3.4.3.1 <u>Equipment/data checks, maintenance</u>. Equipment data checks and maintenance activities accounted for 2 hours of site usage time. These activities included changing out batteries and performing routine data checks to ensure the data were being properly recorded/collected. Gap spent an additional 13 hours and 31 minutes for breaks and lunches.

3.4.3.2 <u>Equipment failure or repair</u>. No time was required for equipment failure or repair.

3.4.3.3 <u>Weather</u>. No weather delays occurred during the survey.

3.4.4 Data Collection

Gap spent a total time of 105 hours and 19 minutes in the open field area, of which 78 hours and 23 minutes were spent collecting data.

3.4.5 Demobilization

The Gap survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 2 July 2008. On that day, it took the crew 3 hours and 30 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

Gap submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data were provided in August 2009, well outside of the required 45-day time frame.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Steve Griffith
Paul O'Donnell
Christopher Parker
Ian Wilson
Joanna Jago

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

Gap surveyed the open field in a linear manner and in a south-to-north and east-to-west direction, using the width of the array for line spacing.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive are shown in Figure 2. Both probabilities plotted against their respective background alarm rate are shown in Figure 3. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

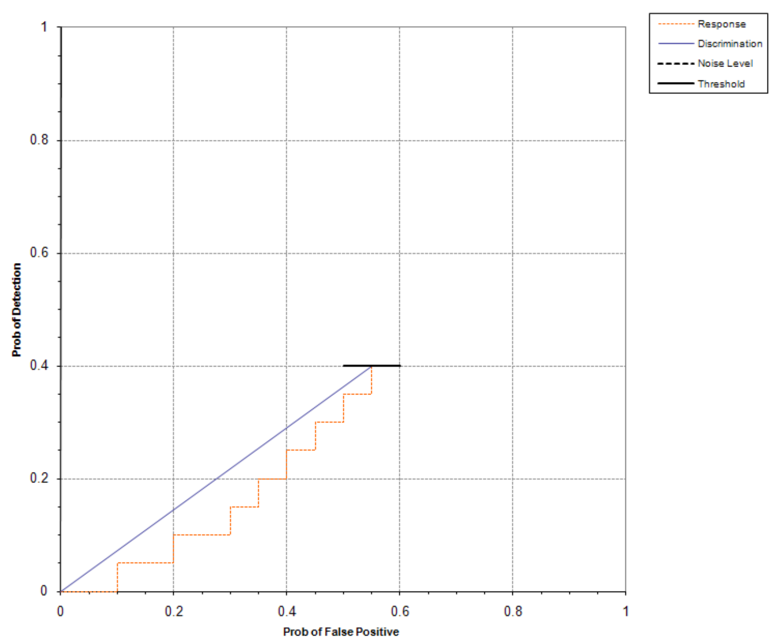

Figure 2. SAM/towed probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

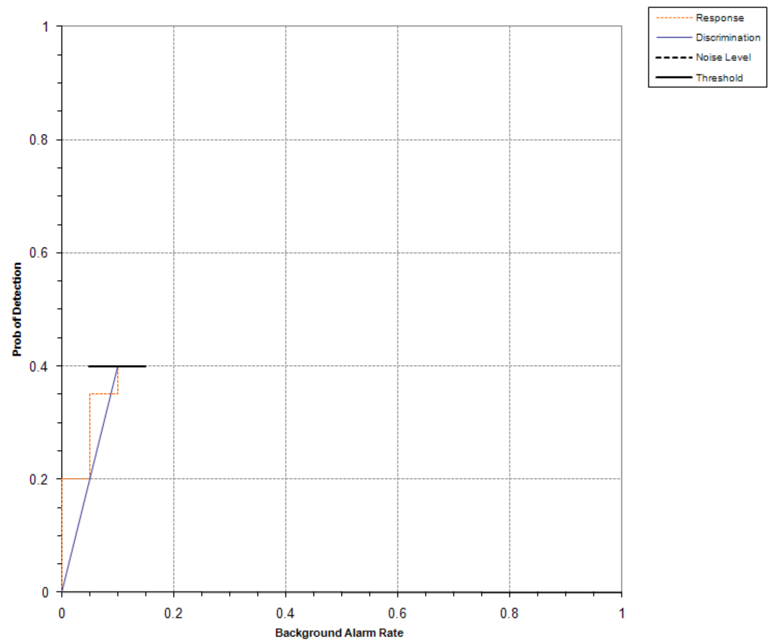

Figure 3. SAM/towed probability of detection for response and discrimination stages versus their respective background alarm rate over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored are shown in Figure 4. Both probabilities plotted against their respective background alarm rate is shown in Figure 5. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

NA

Figure 4. SAM/towed probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

NA

Figure 5. SAM/towed probability of detection for response and discrimination stages versus their respective background alarm rate for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the open field, broken out by size, depth, and nonstandard ordnance, are presented in Table 5 (for cost results, see section 5). Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range (see app A for size definitions). The results are relative to the number of ordnance items emplaced. Depth is measured from the geometric center of anomalies.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

TABLE 5. SUMMARY OF OPEN FIELD RESULTS FOR SAM/TOWED

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.35	0.35	0.45	0.20	0.45	0.70	0.30	0.50	0.25
P_d Low 90% Conf	0.34	0.30	0.39	0.16	0.42	0.63	0.28	0.46	0.18
P_d Upper 90% Conf	0.40	0.36	0.48	0.22	0.52	0.76	0.34	0.56	0.38
P_{fp}	0.55	-	-	-	-	-	0.55	0.60	0.00
P_{fp} Low 90% Conf	0.54	-	-	-	-	-	0.53	0.56	0.00
P_{fp} Upper 90% Conf	0.57	-	-	-	-	-	0.57	0.63	0.21
BAR	0.10	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.35	0.35	0.45	0.20	0.45	0.70	0.30	0.50	0.25
P_d Low 90% Conf	0.34	0.30	0.39	0.16	0.42	0.63	0.28	0.46	0.18
P_d Upper 90% Conf	0.40	0.36	0.48	0.22	0.52	0.76	0.34	0.56	0.38
P_{fp}	0.55	-	-	-	-	-	0.55	0.60	0.00
P_{fp} Low 90% Conf	0.54	-	-	-	-	-	0.53	0.56	0.00
P_{fp} Upper 90% Conf	0.57	-	-	-	-	-	0.57	0.63	0.21
BAR	0.10	-	-	-	-	-	-	-	-

Response Stage Noise Level: 7.00.
Recommended Discrimination Stage Threshold: 233.50.

Note: The recommended discrimination stage threshold values are provided by the demonstrator.

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	1.00	0.00	0.00
With No Loss of P_d	1.00	0.00	0.00

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 7). Correct type examples include 20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket. A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are 20 mmP, 105 H, and 2.75 in., respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	Percentage Correct
Small	NA
Medium	NA
Large	NA
Overall	NA

Note: The demonstrator did not attempt to provide type classification.

4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the blind grid, only depth errors are calculated because (X, Y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION (M)

	Mean	Standard Deviation
Northing	-0.11	0.17
Easting	-0.02	0.18
Depth	0.38	0.32

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SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated supervisor, the second person was designated data analyst, and the third and following personnel were considered field support. Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the calibration lanes as well as field calibrations. Site survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	12.08	$1147.60
Data analyst	1	57.00	12.08	688.56
Field support	2	28.50	12.08	688.56
Subtotal				**$2524.72**
Calibration				
Supervisor	1	$95.00	5.92	$562.40
Data analyst	1	57.00	5.92	337.44
Field support	2	28.50	5.92	337.44
Subtotal				**$1237.28**
Site Survey				
Supervisor	1	$95.00	105.31	$10004.45
Data analyst	1	57.00	105.31	6002.67
Field support	2	28.50	105.31	6002.67
Subtotal				**$22009.79**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	3.50	$332.50
Data analyst	1	57.00	3.50	199.50
Field support	3	28.50	3.50	299.25
Subtotal				**$831.25**
Total				**26603.04**

Notes: Calibration time includes time spent in the calibration lanes as well as calibration before each data run.
Site survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO BLIND GRID DEMONSTRATION (BASED ON COMBINED EM/MAG DATA SETS)

6.1 SUMMARY OF RESULTS FROM BLIND GRID DEMONSTRATION

Table 10 shows the results from the blind grid survey conducted prior to surveying the open field during the same site visit in June 2008. Due to the system utilizing magnetometer type sensors, all results presented in the following section have been based on performance scoring against the ferrous only ground truth anomalies. For more details on the blind grid survey results reference section 2.1.6.

TABLE 10. SUMMARY OF BLIND GRID RESULTS FOR THE SAM/TOWED

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.75	0.75	0.80	0.75	0.80	0.80	0.85	0.80	0.00
P_d Low 90% Conf	0.69	0.64	0.67	0.63	0.63	0.58	0.75	0.69	0.00
P_d Upper 90% Conf	0.82	0.82	0.89	0.83	0.89	0.92	0.91	0.91	0.28
P_{fp}	1.00	-	-	-	-	-	1.00	0.95	NA
P_{fp} Low 90% Conf	0.95	-	-	-	-	-	0.97	0.83	NA
P_{fp} Upper 90% Conf	1.00	-	-	-	-	-	1.00	0.98	NA
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.75	0.75	0.80	0.75	0.80	0.80	0.85	0.80	0.00
P_d Low 90% Conf	0.69	0.64	0.67	0.63	0.63	0.58	0.75	0.69	0.00
P_d Upper 90% Conf	0.82	0.82	0.89	0.83	0.89	0.92	0.91	0.91	0.28
P_{fp}	1.00	-	-	-	-	-	1.00	0.95	NA
P_{fp} Low 90% Conf	0.95	-	-	-	-	-	0.97	0.83	NA
Pfp Upper 90% Conf	1.00	-	-	-	-	-	1.00	0.98	NA
P_{ba}	0.05	-	-	-	-	-	-	-	-

6.2 COMPARISON OF ROC CURVES USING ALL ORDNANCE CATEGORIES

The P_d^{res} versus the respective P_{fp} over all ordnance categories is shown in Figure 6. The P_d^{disc} versus the respective P_{fp} over all ordnance categories is shown in Figure 7. Horizontal lines illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination. The ROC curves in this section are a sole reflection of the ferrous only survey.

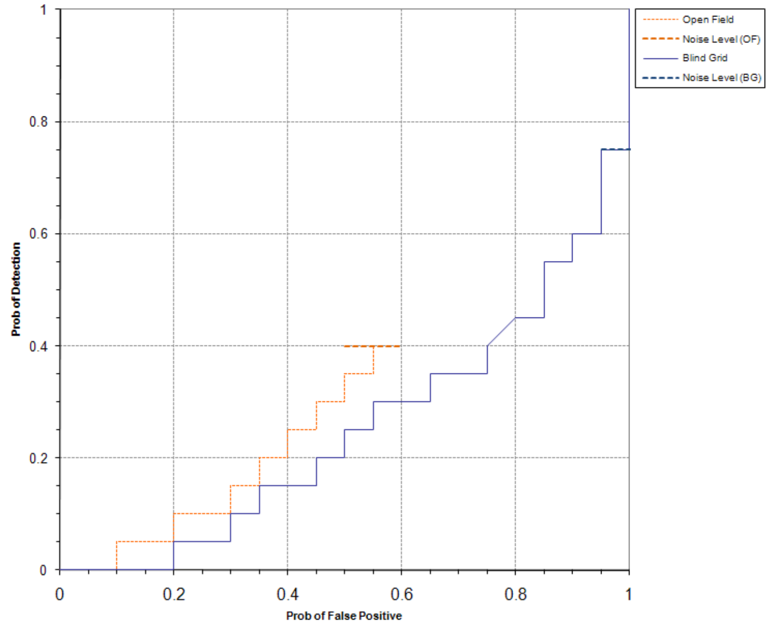

Figure 6. SAM/towed P_d^{res} stages versus the respective P_{fp} over all ordnance categories combined.

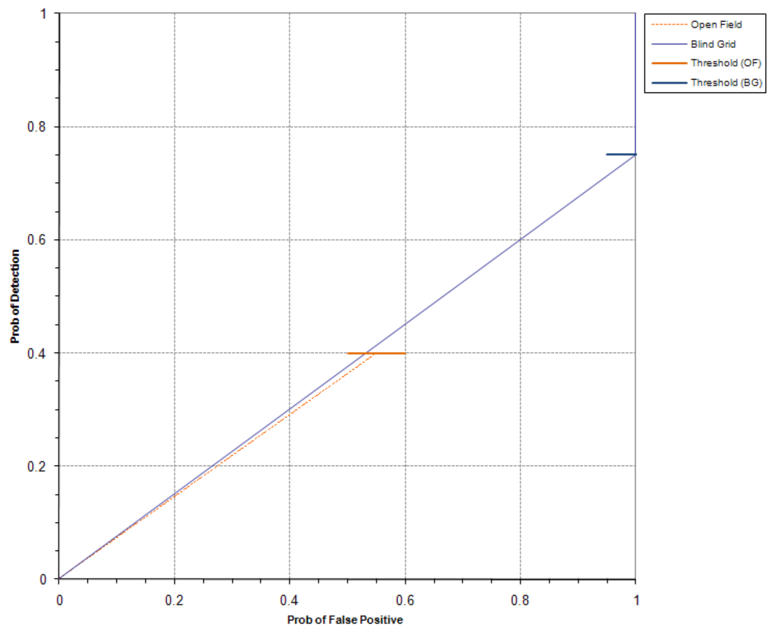

Figure 7. SAM/towed P_d^{disc} versus the respective P_{fp} over all ordnance categories combined.

6.3 COMPARISON OF ROC CURVES USING ORDNANCE LARGER THAN 20 MM

The P_d^{res} versus the respective probability of P_{fp} over ordnance larger than 20 mm is shown in Figure 8. The P_d^{disc} versus the respective P_{fp} over ordnance larger than 20 mm is shown in Figure 9. Horizontal lines illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination.

NA

Figure 8. SAM/towed P_d^{res} versus the respective P_{fp} for ordnance larger than 20 mm.

NA

Figure 9. SAM/towed P_d^{disc} versus the respective P_{fp} for ordnance larger than 20 mm.

6.4 STATISTICAL COMPARISONS

Statistical Chi-square significance tests were used to compare results between the blind grid and open field scenarios. The intent of the comparison is to determine if the feature introduced in each scenario has a degrading effect on the performance of the sensor system. However, any modifications in the UXO sensor system during the test, like changes in the processing or changes in the selection of the operating threshold, will also contribute to performance differences.

The Chi-square test for comparison between ratios was used at a significance level of 0.05 to compare blind grid to open field with regard to P_d^{res}, P_d^{disc}, P_{fp}^{res} and P_{fp}^{disc}, Efficiency and Rejection Rate. These results are presented in Table 11. A detailed explanation and example of the Chi-square application is located in Appendix A.

TABLE 11. CHI-SQUARE RESULTS - BLIND GRID VERSUS OPEN FIELD

Metric	Small	Medium	Large	Overall
P_d^{res}	Significant	Significant	Not significant	Significant
P_d^{disc}	Significant	Significant	Not significant	Significant
P_{fp}^{res}	-	-	-	Significant
P_{fp}^{disc}	-	-	-	Significant
Efficiency	-	-	-	Not significant
Rejection rate	-	-	-	Not significant

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Munitions and Explosives Of Concern (MEC): Specific categories of military munitions that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g. TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the blind grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind Grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open Field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to non-ordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

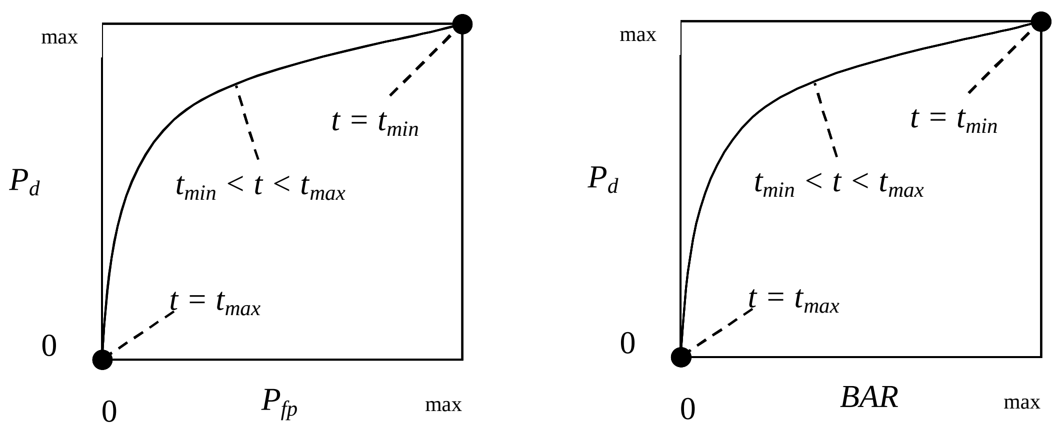

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the blind grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage t_{min}) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})]$).

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X's system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the Chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind grid	Open field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B.   DAILY WEATHER LOGS

Date, 08	Time, EST	Average Temperature, °F	Average Precipitation, in.
18 Jun	0700	73.9	0.00
	0800	80.4	0.00
	0900	83.5	0.00
	1000	85.3	0.00
	1100	86.7	0.00
	1200	87.8	0.00
	1300	88.3	0.00
	1400	89.1	0.00
	1500	89.6	0.00
	1600	90.0	0.00
	1700	89.8	0.00
19 Jun	0700	79.0	0.00
	0800	88.1	0.00
	0900	92.4	0.00
	1000	97.4	0.00
	1100	102.8	0.00
	1200	106.6	0.00
	1300	109.5	0.00
	1400	111.3	0.00
	1500	112.7	0.00
	1600	113.1	0.00
	1700	113.4	0.00
20 Jun	0700	80.6	0.00
	0800	88.1	0.00
	0900	94.0	0.00
	1000	100.2	0.00
	1100	104.3	0.00
	1200	108.3	0.00
	1300	111.7	0.00
	1400	113.5	0.00
	1500	114.9	0.00
	1600	115.1	0.00
	1700	115.7	0.00

Date, 08	Time, EST	Average Temperature, oF	Average Precipitation, in.
21 Jun	0700	81.5	0.00
	0800	89.4	0.00
	0900	92.5	0.00
	1000	98.0	0.00
	1100	102.0	0.00
	1200	104.9	0.00
	1300	107.7	0.00
	1400	109.8	0.00
	1500	111.4	0.00
	1600	112.5	0.00
	1700	112.8	0.00
23 Jun	0700	89.0	0.00
	0800	94.5	0.00
	0900	97.0	0.00
	1000	98.8	0.00
	1100	100.0	0.00
	1200	102.7	0.00
	1300	105.7	0.00
	1400	108.1	0.00
	1500	110.1	0.00
	1600	110.1	0.00
	1700	110.7	0.00
24 Jun	0700	81.7	0.00
	0800	88.9	0.00
	0900	94.7	0.00
	1000	97.5	0.00
	1100	99.3	0.00
	1200	100.9	0.00
	1300	103.4	0.00
	1400	105.7	0.00
	1500	106.7	0.00
	1600	107.0	0.00
	1700	108.0	0.00
25 Jun	0700	81.6	0.00
	0800	87.4	0.00
	0900	92.5	0.00
	1000	95.9	0.00
	1100	98.8	0.00
	1200	101.3	0.00
	1300	102.6	0.00
	1400	104.7	0.00
	1500	106.3	0.00
	1600	107.1	0.00
	1700	107.1	0.00

Date, 08	Time, EST	Average Temperature, oF	Average Precipitation, in.
26 Jun	0700	78.8	0.00
	0800	83.8	0.00
	0900	88.0	0.00
	1000	91.3	0.00
	1100	95.2	0.00
	1200	97.7	0.00
	1300	100.2	0.00
	1400	102.0	0.00
	1500	103.9	0.00
	1600	104.8	0.00
	1700	105.6	0.00
27 Jun	0700	82.1	0.00
	0800	88.7	0.00
	0900	92.9	0.00
	1000	97.0	0.00
	1100	99.3	0.00
	1200	101.0	0.00
	1300	103.7	0.00
	1400	105.6	0.00
	1500	106.3	0.00
	1600	105.9	0.00
	1700	106.1	0.00
28 Jun	0700	82.7	0.00
	0800	89.8	0.00
	0900	94.5	0.00
	1000	98.6	0.00
	1100	100.8	0.00
	1200	103.2	0.00
	1300	104.7	0.00
	1400	106.5	0.00
	1500	107.3	0.00
	1600	107.2	0.00
	1700	107.5	0.00

APPENDIX C. SOIL MOISTURE

Date: 18 Jun 08			
Times: 0930 and 1445			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Calibration area	0 to 6	3.7	1.1
	6 to 12	6.0	7.7
	12 to 24	9.1	10.0
	24 to 36	4.6	4.3
	36 to 48	9.7	9.7
Mogul field	0 to 6	0.5	2.2
	6 to 12	0.2	38.2
	12 to 24	6.3	8.1
	24 to 36	11.6	11.3
	36 to 48	15.1	15.4
Desert extreme area	0 to 6	11.1	11.1
	6 to 12	38.2	38.2
	12 to 24	2.0	2.0
	24 to 36	7.6	7.5
	36 to 48	8.1	7.6

Date: 1 Jul 08			
Times: 1530 and 1300			
Probe Location	**Layer, in.**	**AM Reading, %**	**PM Reading, %**
Calibration area	0 to 6	2.8	4.0
	6 to 12	6.6	6.3
	12 to 24	9.7	8.8
	24 to 36	4.5	4.6
	36 to 48	9.9	9.9
Mogul field	0 to 6	1.4	0.5
	6 to 12	4.0	38.2
	12 to 24	6.2	8.1
	24 to 36	12.0	11.8
	36 to 48	15.7	15.3
Desert extreme area	0 to 6	40.0	40.0
	6 to 12	38.2	38.2
	12 to 24	1.4	2.1
	24 to 36	7.5	7.6
	36 to 48	8.5	8.1

APPENDIX D. DAILY ACTIVITY LOGS

Date, 08	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
16 Jun	2	CALIBRATION LANES	0700	1100	240	INITIAL SETUP	SETTING UP TEST EQUIPMENT AND INITIAL CALIBRATION	NA	NA	SUNNY	WARM
16 Jun	4	CALIBRATION LANES	1100	1200	60	INITIAL SETUP	SETTING UP TEST EQUIPMENT AND INITIAL CALIBRATION	NA	NA	SUNNY	WARM
16 Jun	4	CALIBRATION LANES	1200	1300	60	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	WARM
16 Jun	4	CALIBRATION LANES	1300	1615	195	INITIAL SETUP	SETTING UP TEST EQUIPMENT AND INITIAL CALIBRATION	NA	NA	SUNNY	WARM
16 Jun	4	CALIBRATION LANES	1615	1630	15	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	SUNNY	WARM
17 Jun	4	CALIBRATION LANES	0620	1010	230	INITIAL SETUP	SETTING UP TEST EQUIPMENT AND INITIAL CALIBRATION	GPS	Linear	SUNNY	WARM
17 Jun	4	CALIBRATION LANES	1010	1110	60	BREAK/LUNCH	BREAK, VERIFYING DATA	Na	Na	SUNNY	WARM
17 Jun	4	CALIBRATION LANES	1110	1205	55	CALIBRATION	INITIAL CALIBRATION	GPS	LINEAR	SUNNY	HOT
17 Jun	4	CALIBRATION LANES	1205	1245	40	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
17 Jun	4	CALIBRATION LANES	1245	1500	135	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
17 Jun	4	CALIBRATION LANES	1500	1530	30	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	SUNNY	HOT
18 Jun	4	CALIBRATION LANES	0525	0600	35	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
18 Jun	4	BLIND TEST GRID	0600	0630	30	COLLECTING DATA	COLLECTING DATA, NORTH - SOUTH, EAST - WEST	GPS	LINEAR	SUNNY	WARM
18 Jun	4	BLIND TEST GRID	0630	0650	20	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOADING AND VERIFYING DATA	NA	NA	SUNNY	WARM
18 Jun	4	BLIND TEST GRID	0650	0750	60	COLLECTING DATA	COLLECTING DATA, NORTH - SOUTH, EAST - WEST	GPS	LINEAR	SUNNY	WARM

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 08	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
18 Jun	4	BLIND TEST GRID	0750	0800	10	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	DOWNLOADING AND VERIFYING DATA	NA	NA	SUNNY	WARM
18 Jun	4	BLIND TEST GRID	0800	0915	75	COLLECTING DATA	COLLECTING DATA, NORTH - SOUTH, EAST - WEST	GPS	LINEAR	SUNNY	WARM
18 Jun	4	OPEN FIELD	0915	1045	90	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	RELOCATING EQUIPMENT, FLAG GRID	NA	NA	SUNNY	WARM
18 Jun	4	OPEN FIELD	1045	1145	60	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
18 Jun	4	OPEN FIELD	1145	1215	30	DOWNTIME DUE TO EQUIPMENT MAINTENANCE/CHECK	RELOCATING EQUIPMENT, FLAG GRID	NA	NA	SUNNY	HOT
18 Jun	4	OPEN FIELD	1215	1415	120	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
18 Jun	4	OPEN FIELD	1415	1430	15	DAILY START, STOP	BREAKDOWN END OF DAY	NA	NA	SUNNY	HOT
19 Jun	4	OPEN FIELD	0517	0545	28	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
19 Jun	4	OPEN FIELD	0545	0910	205	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
19 Jun	4	OPEN FIELD	0910	0930	20	BREAK/LUNCH	BREAK, DOWNLOAD DATA	NA	NA	SUNNY	HOT
19 Jun	4	OPEN FIELD	0930	1145	135	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
19 Jun	4	OPEN FIELD	1145	1245	60	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
19 Jun	4	OPEN FIELD	1245	1420	95	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
19 Jun	4	OPEN FIELD	1420	1430	10	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
20 Jun	4	OPEN FIELD	0528	0558	30	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	GPS	LINEAR	SUNNY	COOL
20 Jun	4	OPEN FIELD	0558	0858	180	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	NA	NA	SUNNY	WARM

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 08	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
20 Jun	4	OPEN FIELD	0858	0929	31	BREAK/LUNCH	BREAK	GPS	LINEAR	SUNNY	WARM
20 Jun	4	OPEN FIELD	0929	1133	124	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	NA	NA	SUNNY	WARM
20 Jun	4	OPEN FIELD	1133	1228	55	BREAK/LUNCH	LUNCH	GPS	LINEAR	SUNNY	HOT
20 Jun	4	OPEN FIELD	1228	1420	112	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	NA	NA	SUNNY	HOT
20 Jun	4	OPEN FIELD	1420	1434	14	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
21 Jun	4	OPEN FIELD	0525	0605	40	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	COOL
21 Jun	4	OPEN FIELD	0605	0845	160	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	COOL
21 Jun	4	OPEN FIELD	0845	0930	45	BREAK/LUNCH	BREAK	NA	NA	SUNNY	COOL
21 Jun	4	OPEN FIELD	0930	1115	105	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
21 Jun	4	OPEN FIELD	1115	1200	45	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	WARM
21 Jun	4	OPEN FIELD	1200	1420	140	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
21 Jun	4	OPEN FIELD	1420	1430	10	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	WARM
23 Jun	4	OPEN FIELD	0518	0620	62	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
23 Jun	4	OPEN FIELD	0620	0935	195	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	COOL
23 Jun	4	OPEN FIELD	0935	1005	30	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
23 Jun	4	OPEN FIELD	1005	1145	100	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
23 Jun	4	OPEN FIELD	1145	1245	60	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	WARM
23 Jun	4	OPEN FIELD	1245	1422	97	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
23 Jun	4	OPEN FIELD	1422	1435	13	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 08	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
24 Jun	4	OPEN FIELD	0512	0610	58	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
24 Jun	4	OPEN FIELD	0610	0920	190	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
24 Jun	4	OPEN FIELD	0920	1015	55	BREAK/LUNCH	BREAK/VISIT WITH HIGH SCHOOL STUDENT	NA	NA	SUNNY	WARM
24 Jun	4	OPEN FIELD	1015	1145	90	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
24 Jun	4	OPEN FIELD	1145	1240	55	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
24 Jun	4	OPEN FIELD	1240	1420	100	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
24 Jun	4	OPEN FIELD	1420	1433	13	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
25 Jun	4	OPEN FIELD	0522	0610	48	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
25 Jun	4	OPEN FIELD	0610	0910	180	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
25 Jun	4	OPEN FIELD	0910	0945	35	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
25 Jun	4	OPEN FIELD	0945	1200	135	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
25 Jun	4	OPEN FIELD	1200	1240	40	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
25 Jun	4	OPEN FIELD	1240	1400	80	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
25 Jun	4	OPEN FIELD	1400	1420	20	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
26 Jun	4	OPEN FIELD	0514	0610	56	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	COOL
26 Jun	4	OPEN FIELD	0610	1045	275	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
26 Jun	4	OPEN FIELD	1045	1115	30	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 08	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
26 Jun	4	OPEN FIELD	1115	1330	135	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
26 Jun	4	OPEN FIELD	1330	1340	10	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
27 Jun	4	OPEN FIELD	0540	0630	50	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	COOL
27 Jun	4	OPEN FIELD	0630	0915	165	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	COOL
27 Jun	4	OPEN FIELD	0915	0935	20	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
27 Jun	4	OPEN FIELD	0935	1130	115	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
27 Jun	4	OPEN FIELD	1130	1210	40	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	WARM
27 Jun	4	OPEN FIELD	1210	1400	110	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
27 Jun	4	OPEN FIELD	1400	1415	15	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
28 Jun	4	OPEN FIELD	0515	0550	35	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	COOL
28 Jun	4	OPEN FIELD	0550	0845	175	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	COOL
28 Jun	4	OPEN FIELD	0845	0900	15	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
28 Jun	4	OPEN FIELD	0900	1130	150	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
28 Jun	4	OPEN FIELD	1130	1200	30	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
30 Jun	4	OPEN FIELD	0510	0550	40	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
30 Jun	4	OPEN FIELD	0550	0820	150	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
30 Jun	4	OPEN FIELD	0820	0845	25	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
30 Jun	4	OPEN FIELD	0845	1130	165	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

Date, 08	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
30 Jun	4	OPEN FIELD	1130	1150	20	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
30 Jun	4	OPEN FIELD	1150	1236	46	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
30 Jun	4	OPEN FIELD	1236	1245	9	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
1 Jul	4	OPEN FIELD	0514	0603	0	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
1 Jul	4	OPEN FIELD	0603	0845	162	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
1 Jul	4	OPEN FIELD	0845	0910	25	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
1 Jul	4	OPEN FIELD	0910	1145	155	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
1 Jul	4	BLIND TEST GRID	1145	1245	60	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
1 Jul	4	BLIND TEST GRID	1245	1420	95	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
1 Jul	4	BLIND TEST GRID	1420	1435	15	DAILY START, STOP	BREAKDOWN, END OF DAY	NA	NA	SUNNY	HOT
2 Jul	4	OPEN FIELD	0545	0615	30	DAILY START, STOP	SETUP OF EQUIPMENT AND CALIBRATION	NA	NA	SUNNY	WARM
2 Jul	4	OPEN FIELD	0615	0830	135	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
2 Jul	3	OPEN FIELD	0830	0940	70	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
2 Jul	5	OPEN FIELD	0940	1000	20	BREAK/LUNCH	BREAK	NA	NA	SUNNY	WARM
2 Jul	3	OPEN FIELD	1000	1200	120	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	WARM
2 Jul	5	OPEN FIELD	1200	1225	25	BREAK/LUNCH	LUNCH	NA	NA	SUNNY	HOT
2 Jul	3	OPEN FIELD	1225	1300	35	COLLECTING DATA	COLLECTING DATA, SOUTH - NORTH, WEST - EAST	GPS	LINEAR	SUNNY	HOT
2 Jul	5	CONNEX	1300	1630	210	DAILY START, STOP	BREAK DOWN, END OF TEST	NA	NA	SUNNY	HOT

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

5. Practical Nonparametric Statistics, W.J. Conover, John Wiley & Sons, 1980, pages 144 through 151.

APPENDIX F. ABBREVIATIONS

APG	=	Aberdeen Proving Ground
ATC	=	U.S. Army Aberdeen Test Center
ATSS	=	Aberdeen Test Support Services
BAR	=	background alarm rate
DMM	=	discarded military munitions
E	=	efficiency
ERDC	=	U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
EQT	=	Army Environmental Quality Technology Program
GPS	=	Global Positioning System
HDSD	=	Homeland Defense and Sustainment Division
HEAT	=	high-explosive antitank
JPG	=	Jefferson Proving Ground
M	=	standard deviation
MEC	=	munitions and explosives of concern
NS	=	nonstandard
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
SERDP	=	Strategic Environmental Research and Development Program
SL	=	Survivability and Lethality
USAEC	=	U.S. Army Environmental Command
UXO	=	unexploded ordnance
YPG	=	U.S. Army Yuma Proving Ground

APPENDIX G.   DISTRIBUTION LIST

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